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Prediction of Navy E-4 test passers

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THESIS

PREDICTION OF NAVY E-4 TEST PASSERS

by

Edwin Franklin Beach

September 1979

Thesis Advisor: R. R. Read

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PREDICTION OF NAVY E-4 TEST PASSERS

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis applies hierarchical clustering and quadratic discriminant function techniques to the problem of predicting E-4 test passers and non-test passers (including non-test takers) in the Navy. The biographic data base includes items such as test scores and education to serve as separators and predictors in the techniques.

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I. INTRODUCTION

In these days of increasing costs, the Navy must ensure it is recruiting and retaining the best possible personnel. Enlistees should not only have the capacity to do the work, but also the desire and drive to accomplish the assigned tasks. Currently, there are few measures of effectiveness which indicate how an enlistee will perform in the Navy. The SCREEN score, developed by Dr. Robert Lockman of the Center for Naval Analyses, predicts attrition of first term recruits as a function of test score and biographic data [1]. It does not, however, specifically address the performance of a member while in the Navy; rather it predicts survival in the Navy.

The advancement to E-4 is a possible measure of effectiveness with which a member's utility to the Navy could be judged. First, the member must display a certain amount of initiative and drive to prepare for the exam. Second, passing the test is an indication that a member has reached a basic level of knowledge within a specific rating. It is at this point that the Navy begins to get a return on its investment in the member. The E-4 test, therefore, may be used as a measure of both a member's capacity and desire to perform in the Navy.

This thesis explores the differences between the E-4 test passers and non-test passers based on the individual's biographic and demographic data. One would like to know what variables in a member's background are associated with his ability and desire to pass the exam. Specifically, an ordered list of determining factors is desired. Also, it is

important to learn if the determining factors are identical for all ratings or if they vary from rating to rating. Finally, it would be interesting to discover how length of time in service and time in rate are related to a member's tendency to advance.

For the purposes of this analysis, a test passer is defined as a member who has taken the E-4 exam and received a score which caused him to be advanced to E-4. A non-test passer is a member who has either taken the E-4 exam and did not receive a high enough score to be advanced or who did not take the exam even though he was eligible. Most of the non-test passers in the study are non-test takers. The separation of the non-test takers from the non-test passers was not possible due to the lack of data. The reader will need to keep these definitions in mind while reading the text. For clarity, a graphical presentation of these definitions may be found in Figure 1 in Chapter III.

The data used in this study come from all personnel eligible to take the E-4 exam in August 1977. A member was considered eligible if he had at least one year in the Navy and at least six months as an E-3.

Two major results were obtained from this study. First, the use of non-linear discrimination resulted in correct classification of 60 - 70% of the members of each sample examined. Second, hierarchical clustering was applied to group the ratings (especially those with small numbers of members). These groupings may have general use beyond those of this paper.

II. DISCUSSION OF DATA

There are many possible factors which may affect a member's desire and ability to pass the E-4 exam. Examples of these are years of education, job satisifaction, leadership of superiors, sea/shore assignment, etc. Data for some of the more appealing of these was unavailable for the study. The factors used in this analysis were all drawn from the August 1977 monthly Enlisted Master Record (EMR) file located at the Naval Military Personnel Center in Arlington, Virginia. The month of August was chosen because it coincided with a month in which the E-4 exams were given.

The EMR is a 3000 character record which is maintained on each active duty and reserve enlisted member of the Navy. Such items as social security number, pay entry base date, schools attended, and test scores are stored on each record. Each record is a condensed version of a member's personnel jacket.

To make the data easier to manipulate, the 3000 character record file was reduced to a 150 character record file. Each record contained the following demographic data:

Age
Sex
Race
Ethnic group
Home of record
Dependants
Time in rate
Active duty/Reserve duty indicator

Length of service
End of active duty obligation date
Enlistment term
Years of education
Education certification
A-School/No A-School indicator
Special test scores
SCREEN score
Mental aptitude test scores (ASVAB or BTB)

The special test scores measure aptitude in the areas of sonar, electronics, and radio. The SCREEN score is a measure of a recruit's chances of completing the first two years of his enlistment. The mental aptitude tests are a measure of the member's overall intelligence. The Basic Test Battery (BTB) consists of five exams in the areas of general intelligence, numerical reasoning, and mechanical, clerical, and shop aptitude. The Armed Services Vocational Aptitude Battery (ASVAB) contains sixteen tests measuring specific areas of intelligence and aptitude, including the ones in the BTB. Unfortunately, the ASVAB had not been given to a large enough sample of the population to allow it to be used in the analysis.

From the data set, the individuals were extracted whose length of service was at least one year, and whose time in rate was at least six months. These were considered the members eligible to take the E-4 exam. Since completion of correspondence courses and practical factors is not reflected in the EMR, it was not possible to check these eligibility requirements. However, it was assumed that if a member fulfilled the time requirements and desired to take the exam, he would have his other requirements completed.

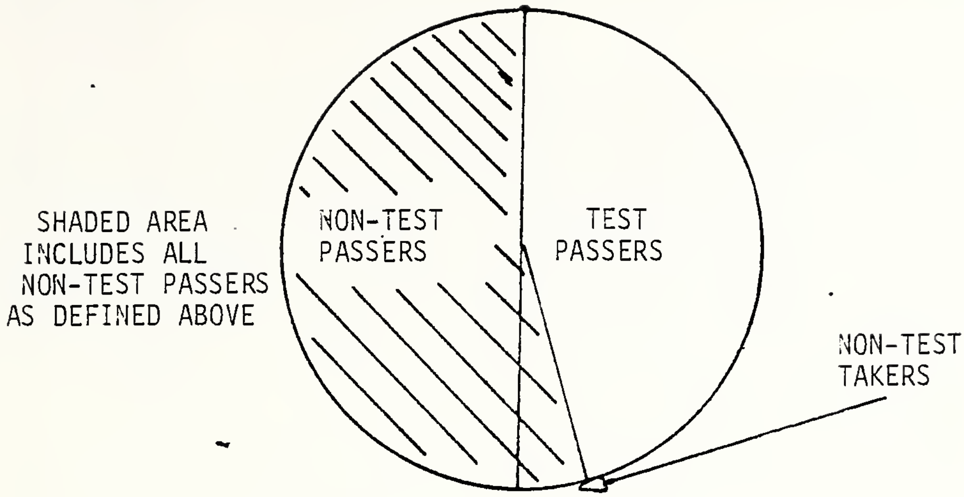
The variables of the data were originally in three

scales; binary, nominal, and interval. Nominal data are data in which numbers are used as labels or "names", e.g., Black=1, Chicano=2, White=3. Binary data were a special form of the nominal where only two responses are available. Interval data include all continuous variables where differences between scores are meaningful. For example, psychological test data are treated as interval data. All of the nominal data were converted to binary values in order to meet the assumptions of the analysis. For instance, the educational certification was transformed from the responses: no degree, GED, high school diploma, Bachelor's degree, and postgraduate degree, to high school diploma or no high school diploma. The GED and college degree holders were grouped with the high school diploma holders.

Some variables were not used in parts or all of the analysis because it was found there were not enough members in the sample with values for these variables. For example, sex could not be used in analyzing the Boiler Technician rating because there were no female members in the sample population. Likewise, the ASVAB scores could not be used because not enough of the sample population had taken this test. Some of the other determining factors were not used because it was decided at the outset that the variable could not be used in policy decisions. Home of record is an example of this type of variable. All variables used in the analysis with a description of their types and ranges are listed in Appendix A.

III. DEFINITION OF GROUPS

Due to the non-availability of data listing all test takers and test passers for the August 1977 cycle, a comparison of the August 1977 EMR and the August 1978 EMR was necessary to determine who passed the exam. The E-4 exam is given only twice a year and all test passers from a given cycle who are advanced to E-4 are advanced from three to nine months after the cycle. Therefore, if a member was eligible to take the exam according to the August 1977 file and was promoted between December 1977 and May 1978, he was classified as a test passer. If he was eligible to take the exam in August 1977 but he was not promoted during the advancement period, he was classified as a non-test passer regardless of whether or not he took the exam. This is illustrated in the Figure 1. Finally, if he was eligible to take the exam in August 1977 and was not in the August 1978 file, he was listed as out of service because it was not possible to determine if he passed the exam or not.



Graphical Representation of Test Passers and Non-test Passers

Figure 1.

Once the groups were determined, it was possible to evaluate the data by either of two methods. First, since the out of service member was in the Navy at the time the test was given, he was actually a test passer or a non-test passer. The assumption would be made that the reason he left the service was that he completed his time in service requirements. Therefore, time alone would distinguish the out of service member from the test passer and the non-test passer. If all factors involving time in the Navy such as length of service and time in rate are ignored, then the test passer and non-test passer groups may be looked on as a random subset of the original test passer / non-test passer / out of service data. This gives just two all inclusive groups as they were found on the day of the test. Unfortunately, one is forced to ignore military time related factors [variables 13, 14, and 15, Appendix A] which might

prove to be useful. Even so, this approach might well be considered useful in evaluating enlistees who as yet have no time in service.

The second method allows the inclusion of military time dependent factors. In this approach the data are viewed at the test cycle plus one year position (August 1978). From this time perspective, a member may fall into only one of the three groups; test passer, non-test passer, or out of service. Since all members are included in this approach and no assumptions of random subsets are made, the time dependant factors may be used. Although classification of out of service personnel may at first seem extraneous to the problem, it is useful knowledge, and may in fact be as important as identifying the test passers.

Both of the above methods of grouping may be applied at various levels of the Navy's structure. First they may be used at the all Navy level. Here all E-3's who meet the time requirements for E-4 would be considered, regardless of rate. Next, the individual ratings may be investigated. Before a member may take an E-4 exam in a particular rating, he must complete certain study and practical factors requirements for that rating. Members in the process of doing this are refered to as designated strikers in that rating and are identified on the EMR file. By analyzing only the designated strikers in a specific rate, it may be possible to predict the test passers for that rate. Finally, for the sample available, certain ratings had too few designated strikers to give any conclusive results. To handle these cases, hierarchical clustering methods could be used to group ratings according to similarity of specified attributes of the ratings. Each group of ratings could then be subjected to analysis.

IV. APPROACHES TO ANALYSIS

The data used in this analysis consisted of fifteen variables per member. The intent was to divide the members into groups according to these variables. Hence, the use of some form of multivariate analysis was dictated.

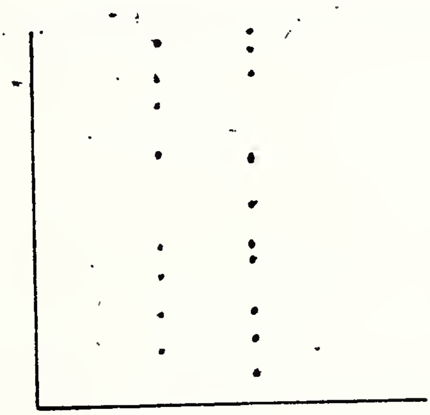
The intent of the analysis was two-fold. First, it was necessary to find out if a difference existed between the groups in terms of the available data. Second, if a difference did exist, was it possible to obtain a classification scheme which would correctly classify an acceptably high percentage of the members?

Discriminant analysis is one method of performing the desired analyses. Discriminant analysis is a multivariate statistical technique used for constructing decision rules by which data units (enlisted members) may be assigned to groups to which they have the greatest resemblance. These decision rules are statistical functions. The independent variables in the functions are the attributes of the member. This analysis is valid for both the two group and the three group case.

There are three basic assumptions underlying discriminant analysis [2]. First, the groups must be discrete and identifiable. Both grouping methods defined in the last section meet this requirement. Second, each observation in each group can be described by a set of m variables. This condition is met by use of the fifteen determining factors. Finally, all m variables are assumed to have a multivariate normal distribution. All of the

interval data for this study were unimodal and symmetric. The data were judged to have a close enough approximation to a normal distribution to meet this assumption. The binary data, of course did not. However, according to Gilbert |3|, binary data may be used with little loss of discriminating power. This is because the rotations of the axes which occur in discriminant analysis cause the binary data to appear to be binary no longer.

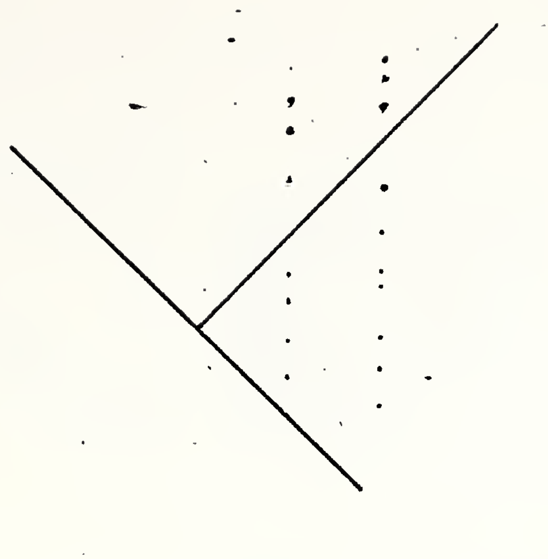
As an example, consider a two space problem of binary vs. interval data:



Binary vs. Interval Data

Figure 2.

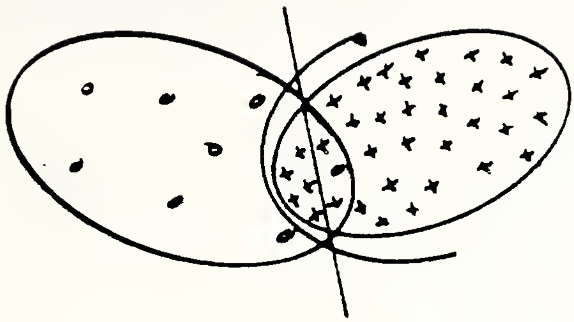
If the axis is rotated to obtain a discriminant function, the data no longer appear to be binary vs. interval, but interval vs. interval as shown in the following figure.



Transformed Binary vs. Interval Data

Figure 3.

Given that all the basic assumptions for the use of discriminant analysis are satisified, the type of discriminant function must be chosen. If the variance-covariance matrices of the groups are equal, a linear function may be used. If they are not equal the better discrimination is achieved by a quadratic function. A two-dimensional illustration of this is shown in the following diagram. The inequality of the covariance matrices is reflected by the elliptical contours of constant density.



Quadratic vs. Linear Discriminating Functions

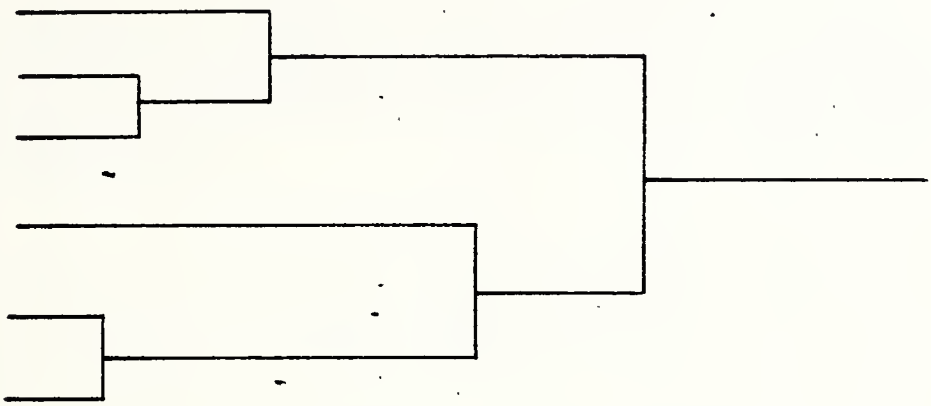
Figure 4.

The quadratic function above misclassifies only one data point, whereas the linear function misclassifies five points. When given a choice, even if the variance-covariance matrices are equal, it is wise to choose the quadratic function. The quadratic should always perform at least as well as the linear function.

As was stated in Chapter III, some ratings do not have a large enough sample in any testing cycle to allow one to conduct a meaningful analysis. To resolve this problem, cluster analysis was used to group the ratings.

There are several methods of cluster analysis available. The particular type used in this study is termed hierarchical clustering. For this method, the data attributes of each entity (rating) are investigated to determine which two entities are the most alike [4]. These two entities are clustered together to form a new entity and an averaged set of variables is computed for the newly

formed cluster. This cycle is repeated until there is one final cluster containing all of the original entities. The results can be represented as a tree with all the original units on the left and the single cluster on the right.



Hierarchical Clustering Tree

Figure 5.

The major advantage to the hierarchical clustering methods is that they allow one to view the overall relationships among the data units. The tree diagram shows the natural clusters which occur and the degree of similarity at the end of each clustering cycle. From this, the analyst is free to choose the optimal number of clusters for his purposes.

V. TECHNICAL DETAILS OF PROCEDURES USED

Discriminant analysis was applied to the data to determine if a difference existed between the group means and, if so, to construct decision rules to place members in the proper groups.

The first step in the analysis was to determine if the variance-covariance matrices of the groups were equal. The results of this dictated whether or not to use a linear or quadratic discriminating function. In this analysis, every sample produced unequal variance-covariance matrices. Therefore, the quadratic function was used in every case.

Next, the data from each group were investigated to determine if a difference existed between the means of the groups in terms of the variables being investigated. The derivation of the two group case is presented in the following paragraphs. The three group case is found in Appendix B.

For this analysis, the groups were chosen to be of equal size ($N = N_1 = N_2$) and the variance-covariance matrices are assumed to be unequal. N observations from each of the test passer and non-test passer groups may be represented in vector notation as follows, where the n^{th} observation from each group is a 1xm vector

$$x_n = (x_{1,n}, \ldots, x_{m,n})$$

where $n=1, \ldots, N$ and m is the number of variables in each observation. μ_1 and μ_2 are also vectors of length m.

$$\mu_i = (\mu_{1,i}, \ldots, \mu_{m,i})$$

The null hypothesis for this section of the analysis is that the means of the groups in terms of the the determining factors are equal or

$$H_0 : \mu_1 = \mu_2$$

The standard method in univariate statistics for determining if the mean of a population with unknown variance is equal to a specific value is the t-test. Given that the population has a $N(\mu, \sigma^2)$ distribution, the t statistic is defined as follows

$$t = (\sqrt{N}(x-\mu))/S$$

The extention of the t statistic to multivariate analysis is the T^2 statistic which is defined as

$$T^2 = N(x-\mu)'S^{-1}(x-\mu)$$

Now let $y_i = x_{i,1} - x_{i,2}$ and $N = N_1 + N_2$. $\bar{y}$ is defined as

$$\bar{y} = 1/N \sum (x_{i,1} - x_{i,2}) = \bar{x}_1 - \bar{x}_2$$

and the variance-covariance matrix is

$$S = 1/(N-1) \sum (y_i - \bar{y})(y_i - \bar{y})'$$

$$= 1/(N-1) \sum (x_{i,1} - x_{i,2} - \bar{x}_1 + \bar{x}_2)(x_{i,1} - x_{i,2} - \bar{x}_1 + \bar{x}_2)'$$

The T^2 statistic in terms of y is

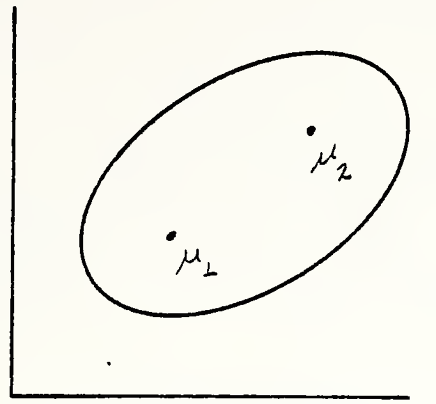
$$T^2 = Ny'S^{-1}y$$

and the null hypothesis as stated above can be rewritten as

$$H_0 : \mu_1 - \mu_2 = 0$$

to accomodate T^2 in terms of y.

The object of the T^2 test is to find a confidence region about μ_1 and μ_2 as shown below. The size of the confidence region is dependent on α, the level of significance of the test.



Confidence Region About $\mu_1 - \mu_2$

Figure 6.

With a scaling change, the T^2 statistic is distributed according to an F distribution with m and N-m-1 degrees of freedom |5|.

$$T_N^2 \sim \frac{(N-1)\,m}{N-m-1} F^m_{N-m-1}(\alpha)$$

Therefore, if

$$T_N^2 \frac{(N-m-1)}{(N-2)\,m} \geq F^m_{N-m-1}(\alpha)$$

the hypothesis that the means are equal is rejected.

Once the inequality of the means has been established, the decision rules can be constructed. Again, the two group case will be dealt with here and the three group case can be found in Appendix C.

Anderson states that in addition to the basic discriminant function, the classification function must take into account the a priori probability of group membership and/or the costs of misclassification. Furthermore, he states that, "the good classification scheme minimizes the bad effects of misclassification" |5|. As a means of exploring this, let M be the misclassification function which is to be minimized.

$$M = P(1|2)\pi_2 + P(2|1)\pi_1$$

π_h is the a priori probability of an observation being drawn from group h, and $P(g|h)$ is the probability of classifying an observation as a member of group g when it is actually a member of group h. The costs of misclassification could be included but are unknown and are not dealt with in this study. The quantity M is minimized by the following rule: assign to group one if

$$f_1(X)/f_2(X) \geq \pi_2/\pi_1$$

Otherwise, assign to group two. $f_i(x)$ is the probability density function of population i. Assuming multivariate normal populations with unequal variance-covariance matrices, the above equation becomes

$$\frac{[(2\pi)^{1/2}[\Sigma_1]^{1/2}]^{-1}\ \exp -1/2[(X-\mu_1)'\ {}_1^{-1}\ (X-\mu_1)]}{[(2\pi)^{1/2}[\Sigma_2]^{1/2}]^{-1}\ \exp -1/2[(X-\mu_2)'\ {}_2^{-1}\ (X-\mu_2)]} \geq \frac{\pi_2}{\pi_1}$$

where Σ is the variance. Taking natural logs of both sides and simplifying yields

$$1/2 \ln[\Sigma_2 \cdot \Sigma_1^{-1}] - 1/2[(X-\mu_1)' \Sigma_1^{-1}(X-\mu_1) - (X-\mu_2)'\Sigma_2^{-1}(X-\mu_2)]$$

$$\geq \pi_2/\pi_1$$

By rearranging the equation, the quadratic decision rule is formed.

$$X'(\Sigma_1^{-1} - \Sigma_2^{-1})X - 2(\mu_1'\Sigma_1^{-1} - \mu_2'\Sigma_2^{-1})X + \mu_1'\Sigma_1^{-1}\mu_1 - \mu_2'\Sigma_2^{-1}\mu_2$$

$$\leq \ln[\Sigma_2 \cdot \Sigma_1^{-1}] - 2\ln[\pi_2/\pi_1]$$

If the above equation is true, the observation should be assigned to group 1. If not, assign the observation to group 2.

It is also possible to determine the contribution that each variable makes to the discriminant function. That is, it is possible to compute the relative amount of discriminatory power that each variable has.

Let V_j be an mx1 vector of coefficients of the i^{th} discriminating function. This vector is transformed into a scaled vector V_i' by multiplying each element of v_i by the square root of the corresponding diagonal element of the pooled within groups deviation sum of squares matrix W, where

$$W_{i,i} = (x_{gin} - x_{gi})(x_{gin} - x_{gi})$$

The scaled vector V' is

$$V'_i = [V_{i,1} W_{1,1}, V_{i,2} W_{2,2}, \ldots, V_{i,n} W_{m,m}]$$

The discrimination power of each variable can now be expressed as

$$\frac{V_{i,j}}{\sum V'_{i,j}}$$

The method of hierarchical clustering used in this study is due to Ward [6]. This method is based on the computation of the Euclidean distance between centroids of the entities. For this discussion, let x_{ijk} be the value of the i^{th} variable of the j^{th} data unit in the k^{th} cluster. The mean of the i^{th} variable in the k^{th} cluster is

$$x_{ik} = 1/m_k \; x_{ijk}$$

and the error sum of squares for cluster k is

$$E_k = \quad (x_{ijk} - x_{ik})^2$$

The total within group error sum of squares is

$$E = \sum E_k$$

The criteria for the Ward method is the minimization of the increase in the within group error sum of squares.

$$\Delta E_{pq} = E_t - E_p - E_q$$

where E_p and E_q are the within group error sum of squares for the two entities which are joined to form the cluster t.

By simplification

$$\Delta E_{pq} = \frac{m_p m_q}{m_p + m_q} (x_{ip} - x_{iq})^2$$

This function should force the entities to group into tight clusters. Also, this should cause the distance between the clusters to be at a maximum.

VI. RESULTS OF ANALYSIS

The discriminant analysis discussed in this section was done with the aid of computer routines appearing in Eisenbeis and Avery [2]. These routines use a complete stepwise procedure to guarantee the best discriminant function possible from the given data. This procedure investigates every possible combination of determining factors beginning with a subset of one and continuing up to m factors [2]. For each subset the best combination of variables is chosen. When the analysis is complete, the analyst is free to choose the subset with the best function for his purposes. In this study, all m variables were used in every case.

The analysis was conducted on six samples. The first was at the all Navy level where eligible members were randomly selected without regard to whether they were designated strikers. Next, the ratings in each of the Navy's general assignment categories (Seamen, Firemen, Airmen, and Constructionmen) were subjected to cluster analysis to find which rates tended to be most alike. These clusters were formed using computer routines designed by Anderberg [4]. The variables used to determine the clustering were the average individual ASVAB test scores from the August 1978 cohort. These variables were chosen because they normally remain reasonably constant over a member's career. The averages were computed by summing the test scores (separately for each subtest) for every E-4 through E-6 in each rate and dividing by the number in the rate. Three of the clusters obtained from the Seamen category were subjected to discriminant analysis. The last

two sample populations to be analyzed were individual ratings: the Boiler Technicians and the Machinist's Mates. The following diagram depicts the analyses which were done. The reader may find it helpful to refer to this while reading the suceeding material.

ALL NAVY

2 GROUP	3 GROUP

SN CLSTR 1		SN CLSTR 2		SN CLSTR 4	
2 GROUP	3 GROUP	2 GROUP	3 GROUP	2 GROUP	3 GROUP

BOILER TECH		MACHINIST'S MATE	
2 GROUP	3 GROUP	2 GROUP	3 GROUP

Discriminant Analyses Conducted in this Study

Figure 7.

For the all Navy sample, 300 members of each group, i.e., test passers, non-test passers, and out of service personnel were randomly selected from the eligible pool. First, the two group case, test passers vs. non-test passers was analyzed. After checking the variance-covariance matrices and finding them to be unequal, a comparison of the group means was made. The test for equality of group means produced an F statistic of 3.83 which rejected the null

hypothesis at the 0.01 level of significance (see Appendix D). The variables in this sample which provided the greatest power of discrimination were race (24.5%), high school diploma (20.3%), and dependents (13.59%). The analysis indicated Caucasian members had a higher probability of passing the exam then their non-Caucasian counterparts. Individuals having a high school diploma and/or having dependents also were more likely to pass the exam. A complete list of the determining factors and the amount of discriminating power for each sample population is listed in Appendix E.

Once the discriminant function was computed, the classification of each member was done using a quadratic function as described in Chapter V. The rate of "hits" or correct classification for the all Navy two group sample was 62% (see Appendix H). This classification rate includes the effects of the a priori probability of group membership as do all other classification rates in this study.

The three group case for the all Navy sample was also investigated. Here the equality of the group means was rejected at the 0.01 level of significance. In this case the length of time remaining in service (EAOS), 32.0%, and length of service, 12.27%, proved to be the most powerful determining factors. Both of these variables discriminated best between the out of service group and the other two groups. This is probably because a member with one year or less remaining in his obligation is not likely to take the exam if he is planning to leave the service, because the rewards he will reap are not worth the effort to prepare for the exam. In this sample the rate of hits was 63.0%, which was sligatly better than the two group case.

Clustering analysis of the seamen rates resulted in four clusters (see Appendix F). The ratings tended to group by

job skills: the electronics rates in one cluster, the administrative rates in another, etc. Three of the clusters were subjected to discriminant analysis. The first cluster investigated was cluster four in Appendix F. The test for equality of group means generated an F statistic of 1.99 which was significant at the 2.6% level. The largest discriminating variables in this sample were years of education (21.77%), race (15.0%), the numerical reasoning section of the BTB (13.7%), and the clerical aptitude section of the BTB (10.46%). For this sample 67% of the observations were correctly classified.

Cluster four was also subjected to the three group discriminant analysis. Here the F statistic was 6.25 and was significant at the 10^{-30} level. As in the all Navy group, length of time remaining in service was the largest discriminator (29%), but was followed by the BTB test for shop aptitude (12.09%) and time in service (8.24%). The three group sample was correctly classified 69.0% of the time.

The Seamen rating cluster two, two group sample, was analyzed next. The test for equality of group means was significant at the 12% level, indicating that the means of the groups were close to one another. Since the means were so close, the discriminating variables and the classification rates should be viewed with care.

The three group case of the Seamen cluster two did not test as having equal means and classified 63.0% of the observations correctly. Even so, only 43% of the non-test passers were correctly classified.

The Seamen cluster one consisted mostly of electronics ratings. The two group test of equality of group means

produced an F statistic which was significant at the 45% level. This is hard to accept until one realizes the entry requirements for these rates are very specific. Most entrants have a high school diploma, at least twelve years of school, have gone to A-school, etc. In short, the cluster is sc homogeneous in terms of the available data that it was not possible to discriminate between the groups.

The three group case faired somewhat better as with the other clusters. The test for equality of the means was rejected and the classification was correct 69.0% of the time. However, it must be noted that only 38% of the test passers were correctly classified.

The test of group means for the Boiler Technicians two group sample resulted in an F statistic which was significant at 94%. Because of this, the classification results should be used with care. Even though the three group analysis showed the means were not equal, the percentage of correct classifications was only 50.0%. Again it was this good only because of the addition of the out of service group. The distinction between the test passers and non-test passers was not very good, with only 28.0% of the non-test passers being correctly identified.

The Machinist's Mate rating two group case produced surprising results when the test of the equality of the group means produced an F statistic which was significant at 0.36%. Considering the results of the other samples, one would have expected the significance to be much larger. The most powerful determining factors for this case were the BTB tests for general intelligence (29.91%) and mechanical aptitude (26.44%). Of the total sample, 66% was classified correctly.

The three group test produced an F statistic which was

significant at 10^{-26}. This sample showed time remaining in the Navy to be the most powerful determining factor at 18.05%. Of the total sample, 66% was correctly identified using the decision rules.

From the above results it can be seen that the means in most of the two group samples are too close together to permit any distinct discrimination. This is also true for the three group samples because, although the out of service group is distinct enough to cause the equality of group means test to fail, the test passer and non-test passer groups remain as indistinct as before. The fact that the all Navy sample tested as not having equal means, while all other samples did, appears to be due to the variability of the data in the all Navy case.

VII. CONCLUSIONS

Discriminant analyses and cluster analyses were used in this study as tools to attempt to determine if there was a difference between E-4 test passers and non-test passers in terms of the available biographic data.

The study has shown with a high level of certainty that the available data do not differentiate sharply between the groups. It would appear that the entrance requirements for the Navy or the specific rating create a homogeneous group of personnel in terms of these variables. Since there appears to be nothing in the general biographic background of a member to distinguish between the groups, other possible explanitory variables might be inspected. For instance, where was a member's last duty station, what type of leaders did he have, was he training in a rating he liked?

Although the discriminating variables were not found in the study, the use of the E-4 exam as a measure of effectiveness of a member's utility to the Navy still merits study. Sharper discrimination might result if data reflecting actual test takers is used.

APPENDIX A

LIST OF DETERMINING FACTORS

	FACTOR	TYPE	RANGE
1.	Dependents	Binary	0-No dependents 1 - Dependents
2.	Age	Interval	19-33
3.	Race	Binary	0-Non-Caucasian 1 - Caucasian
4.	Sex	Binary	0 - Female 1 - Male
5.	A-School	Binary	0 - No A-School 1 - A-School
6.	Years of education	Interval	9-16
7.	Education certification	Binary	0 - No high school diploma 1 - High school diploma
8.	BTB (Gen. Intel.)	Interval	31-74
9.	BTB (Num. Reason.)	Interval	32-69

10. BTB (Mech. Apt.)	Interval	37-70
11. BTB (Clr. Apt.)	Interval	38-76
12. BTB (Shop Apt.)	Interval	37-74
13. Time in rate	Interval	6-59 mos
14. Time remaining	Interval	0-48 mos
15. Length of service	Interval	12-72 mos

APPENDIX B

K GROUP TEST FOR EQUALITY OF GROUP MEANS

$$H_0 : \mu_1 = \mu_2 = \ldots = \mu_k$$

This implied $\mu_i - \mu_j = 0$ for $1 \leq i \leq j \leq k$

$$\text{Let } \omega(1) = \mu_1 - \mu_2 = 0$$

$$\omega(2) = \mu_1/2 + \mu_2/2 - \mu_3 = 0$$

$$\vdots$$

$$\omega(k-1) = \mu_1/(k-1) + \mu/(k-1) + \ldots - \mu_{k-1} = 0$$

$$\text{Now } H_0 : \frac{1}{k-1} \sum \omega(i) = 0$$

Which is the form of Anderson's test of the hypothesis |5|.

$$H_0 : \sum \beta_i x_i = 0$$

$$\text{Let } y_i = \beta_1 x_{i,1} + \beta_2 x_{i,2} + \ldots + \beta_k x_{i,k}$$

$$\text{then } y = \quad \beta_i x_i$$

and

$$S = \frac{1}{N-1} \quad (y_i - y)(y_i - y)'$$

$$\text{and } T^2 = N(y- \quad)'S^{-1}(y- \quad)$$

if

$$\frac{T^2(N-m-1)}{(N-2)m} \geq F^{m}_{N-m-1}(\alpha)$$

then reject the equality of group means.

APPENDIX C

K GROUP CLASSIFICATION FUNCTION

Assign to group g if for all other groups h:

$$f_g(x)/f_h(x) \geq \pi_h/\pi_g \qquad h = 1, \ldots, k, \; h = g$$

Assign to group g if for all other groups h:

$$X'(\Sigma_g^{-1} - \Sigma_h^{-1})X - 2(\mu_g'\Sigma_g^{-1} - \mu_h'\Sigma_h^{-1})X + \mu_g'\Sigma_g^{-1}\mu_g - \mu_h'\Sigma_h^{-1}\mu_h$$

$$\geq \ln[\Sigma_h \cdot \Sigma_g^{-1}] - 2\ln[\pi_h/\pi_g]$$

APPENDIX D

TESTS OF EQUALITY OF GROUP MEANS

	EQUALITY OF VARIANCE		EQUALITY OF MEANS	
	F STATISTIC	LEVEL	F STATISTIC	LEVEL
All Navy (2 Group)	1.78	0.0	3.83	0.0
All Navy (3 Group)	2.34	0.0	16.69	0.0
SN Clstr 1 (2 Group)	1.88	0.0	.99	45.29
SN Clstr 1 (3 Group)	2.07	0.0	8.15	0.0
SN Clstr 2 (2 Group)	1.41	.87	1.49	12.36
SN Clstr 2 (3 Group)	1.75	0.0	8.14	0.0
SN Clstr 4 (2 Group)	1.98	0.0	1.99	2.56
SN Clstr 4 (3 Group)	2.06	0.0	6.25	0.0
BT (2 Group)	2.08	0.0	.41	94.70

BT (3 Group)	1.78	0.0	4.46	0.0
MM (2 Group)	1.90	0.0	2.61	.36
MM (3 Group)	2.10	0.0	7.43	0.0

APPENDIX E

POWER OF DETERMINING FACTORS

ALL NAVY

2 GROUP		3 GROUP	
Race	24.50%	Time remaining	32.03%
Edu. Cert.	20.30%	Time in service	12.27%
Dependents	13.59%	Dependents	7.84%
Age	10.55%	Sex	7.45%
BTB (Clr. Apt.)	8.47%	Edu. Cert.	6.99%
BTB (Num. Reason.)	5.58%	Time in rate	6.46%
BTB (Mech. Apt.)	5.28%	BTB (Shop Apt.)	6.04%
A-School	4.69%	BTB (Mech. Apt.)	4.85%
BTB (Gen Intel.)	4.59%	A-School	3.98%
Years of edu.	1.57%	BTB (Clr. Apt.)	3.04%
BTB (Shop Apt.)	0.48%	Race	2.43%
Sex	0.35%	Age	2.05%
		Years of edu.	1.67%
		BTB (Gen. Intel.)	1.49%
		BTB (Num. Reas.)	1.35%

SEAMEN GROUP 1

2 GROUP

BTB (Shop Apt.)	29.43%
BTB (Clr. Apt)	17.88%
BTB (Num. Reason.)	14.32%
BTB (Gen. Intel.)	8.55%
BTB (Mech. Apt.)	6.68%
Dependents	6.07%
A-School	5.14%
Age	4.23%
Race	3.17%
Edu. Cert.	3.14%
Yrs of edu.	1.33%

3 GROUP

Time remaining	35.72%
BTB (Gen. Intel.)	10.95%
BTB (Shop Apt.)	8.82%
Age	8.19%
Time in rate	6.21%
BTB (Clr. Apt.)	6.17%
BTB (Mech. Apt.)	4.89%
Time in service	3.54%
A-School	3.46%
Dependents	3.45%
Edu. cert.	3.38%
BTB (Num. Reason.)	2.18%
Yrs of edu.	1.93%
Race	1.03%

SEAMEN GROUP 2

2 GROUP		3 GROUP	
A-School	17.80%	Time remaining	37.68%
BTB (Mech. Apt.)	14.98%	A-School	6.76%
BTB (Clr. Apt.)	13.35%	Time in rate	6.69%
BTB (Shop Apt.)	11.26%	Dependents	6.24%
Yrs of edu.	9.62%	BTB (Num. Reason.)	5.76%
Edu. cert.	9.17%	Edu. cert.	5.54%
Sex	7.14%	Yr of edu.	5.42%
BTB (Gen. Intel.)	4.85%	Time in service	5.22%
BTB (Num. Reason.)	4.78%	Race	4.52%
Age	2.81%	BTB (Shop Apt.)	3.99%
Dependents	2.40%	BTB (Mech Apt.)	3.57%
Race	1.80%	BTB (Clr. Apt.)	3.49%
		BTB (Gen. Intel.)	2.60%
		Sex	1.39%
		Age	1.05%

SEAMEN GROUP 4

2 GROUP		3 GROUP	
Years of edu.	21.77%	Time remaining	29.27%
Race	15.04%	BTB (Shop Apt.)	12.09%
BTB (Num. Reason.)	13.70%	Time in service	8.24%
BTB (Clr. Apt.)	10.46%	Dependents	7.94%
BTB (Shop Apt.)	10.31%	Edu. cert.	7.14%
Sex	6.13%	BTB (Gen. Intel.)	6.67%
Edu. cert.	6.01%	A-School	4.39%
Dependents	4.52%	Years of edu.	4.15%
BTB (Gen. Intel.)	3.41%	BTB (Num. Reason.)	4.06%
A-School	3.32%	Sex	3.97%
Age	2.89%	Race	3.94%
BTB (Mech. Apt.)	2.39%	Time in rate	2.58%
		BTB (Mech Apt.)	1.96%
		BTB (Clr. Apt.)	1.79%
		Age	1.74%

BOILER TECHNICIAN

2 GROUP		3 GROUP	
BTB (Gen. Intel.)	18.11%	Time remaining	18.05%
BTB (Num. Reason.)	16.96%	Years of edu.	15.39%
BTB (Clr. Apt.)	15.62%	BTB (Shop Apt.)	12.84%
Years of edu.	12.32%	Time in service	10.73%
Edu. cert.	10.30%	Age	10.46%
A-School	9.43%	BTB (Mech. Apt.)	10.25%
BTB (Shop Apt.)	6.99%	Edu. cert.	7.46%
Dependents	4.39%	A-School	3.23%
BTB (Mech. Apt.)	4.05%	BTB (Gen. Intel.)	3.13%
Age	1.42%	Time in rate	2.92%
Race	0.35%	BTB (Num. Reason.)	2.19%
		Dependents	1.39%
		Race	1.30%
		BTB (Clr. Apt.)	0.58%

MACHINIST'S MATE

2 GROUP		3 GROUP	
BTB (Gen. Intel.)	29.91%	Time remaining	29.56%
BTB (Mech. Apt.)	26.44%	BTB (Mech. Apt.)	15.55%
Age	10.01%	Edu. Cert.	11.17%
BTB (Num. Reason.)	9.68%	Time in service	8.30%
BTB (Clr. Apt.)	7.97%	BTB (Gen. Intel.)	6.91%
Dependents	5.15%	Time in rate	6.26%
Years of edu.	5.03%	BTB (Clr. Apt.)	5.29%
A-School	2.41%	Age	4.65%
Race	1.70%	Years of edu.	3.88%
Edu. cert.	1.53%	Race	3.05%
BTB (Shop Apt.)	0.12%	BTB (Shop Apt.)	1.80%
		BTB (Num. Reason.)	1.65%
		A-School	1.62%
		Dependents	0.25%

APPENDIX F

RESULTS OF CLUSTERING OF SEAMEN RATINGS

CLUSTER 1		CLUSTER 2	
STS -	Sonar Tech (S)	SK -	Storekeeper
STG -	Sonar Tech (G)	PC -	Postal Clerk
FTG -	Fire Cntl Tech (gun)	YN -	Yeoman
FTM -	Fire Cntl Tech (missle)	DK -	Dispursing Clerk
FTB -	Fire Cntl Tech (FBM)	MS -	Mess Specialist
ETN -	Electronics Tech (comm)	SH -	Ships serviceman
ETR -	Electronics Tech (radar)	LI -	Lithographer
EW -	Elec Warfare Tech	CTA -	Comm Tech (admin)
CTM -	Comm Tech (maint.)	TM -	Torpedoman's Mate
CTI -	Comm Tech (interp.)	BM -	Boatswain's Mate
DS -	Data Systems Tech		
MT -	Missle Tech		

CLUSTER 3

GMG - Gunner's Mate (gun)
GMM - Gunner's Mate (missles)
GMT - Gunner's Mate (tech)
MN - Mineman
OM - Opticalman
MA - Master at Arms
IM - Instrumentman

CLUSTER 4

CTT - Comm Tech (tech)
CTO - Comm Tech (comm)
CTR - Comm Tech (collection)
DP - Data Processing Tech
IS - Intelligence Spec
PN - Personnelman
RM - Radioman
DM - Draftsman
QM - Quartermaster
OS - Operations Spec
OT - Ocean Sys Spec
MU - Musician
JO - Journalist
LN - Legalman

APPENDIX G

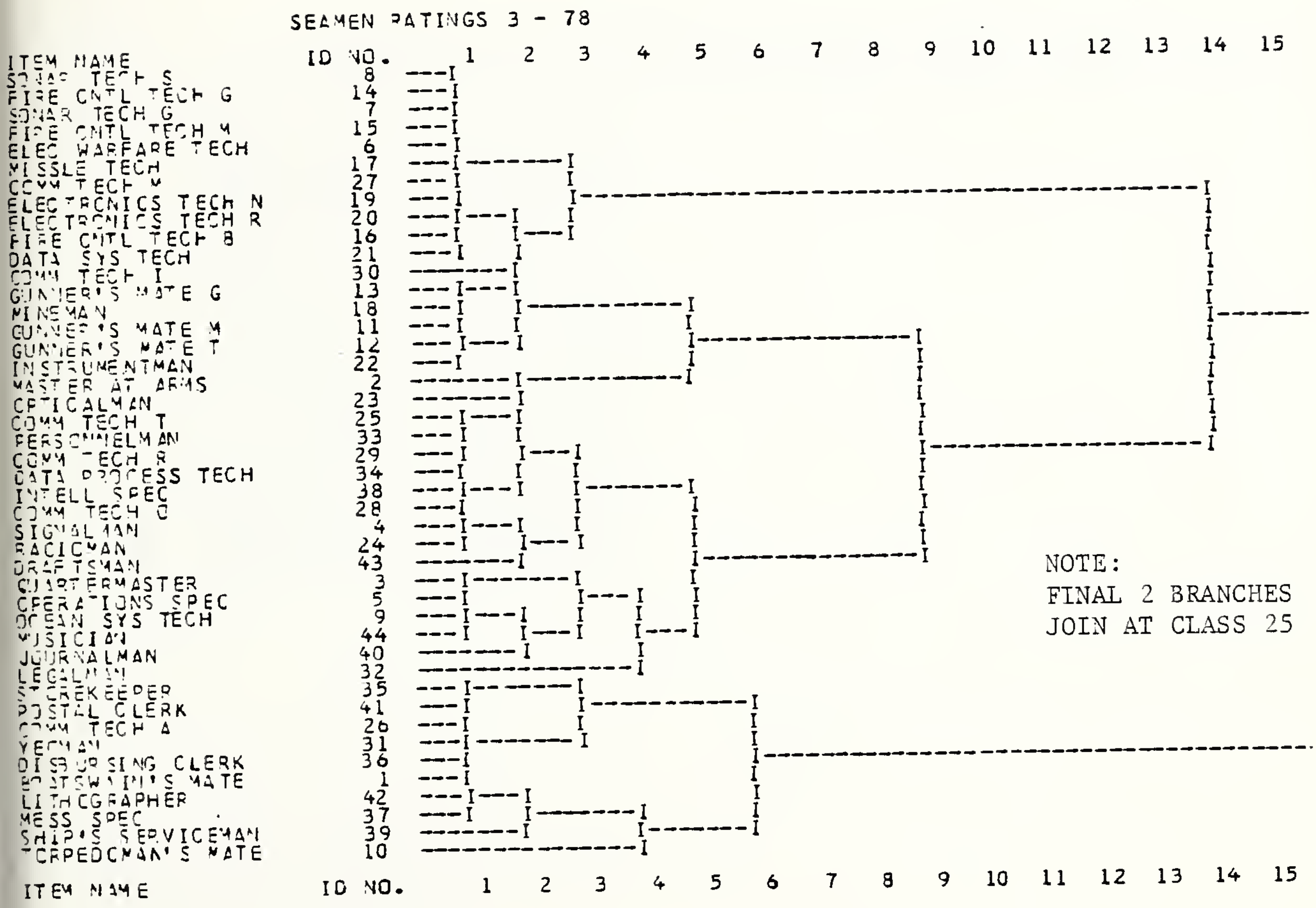
CLASSIFICATION RESULTS

SAMPLE	% CORRECTLY CLASSIFIED			
	TOTAL	TEST PASSERS	NON TEST PASSERS	OUT OF SERVICE
All Navy (2 Group)	62%	80%	45%	--
All Navy (3 Group)	63%	77%	39%	71%
SN Clstr 1 (2 Group)	74%	32%	88%	--
SN Clstr 1 (3 Group)	69%	38%	79%	72%
SN Clstr 2 (2 Group)	63%	77%	49%	--
SN Clstr 2 (3 Group)	63%	71%	43%	76%
SN Clstr 4 (2 Group)	67%	81%	50%	--
SN Clstr 4 (3 Group)	69%	80%	42%	77%
BT (2 Group)	60%	86%	34%	--

BT (3 Group)	57%	80%	28%	60%
MM (2 Group)	66%	71%	60%	--
MM (3 Group)	66%	62%	58%	77%

APPENDIX H

CLUSTERING TREE FOR SEAMEN RATING



SEAMEN RATINGS 3 - 78

THIS RUN DEPICTS THE PORTION OF THE TREE GENERATED BETWEEN STAGE 1 AND STAGE, 43

THE CRITERION VALUES ARE SEGMENTED INTO THE FOLLOWING CLASSES.

CLASS	LOWER BOUND	UPPER BOUND
1	0.14972687E-03	0.19742124E-01
2	0.19742124E-01	0.39334521E-01
3	0.39334521E-01	0.58926918E-01
4	0.58926918E-01	0.78519285E-01
5	0.78519285E-01	0.98111629E-01
6	0.98111629E-01	0.11770397E 00
7	0.11770397E 00	0.13729632E 00
8	0.13729632E 00	0.15688856E 00
9	0.15688856E 00	0.17648101E 00
10	0.17648101E 00	0.19607335E 00
11	0.19607335E 00	0.21566570E 00
12	0.21566570E 00	0.23525804E 00
13	0.23525804E 00	0.25485039E 00
14	0.25485039E 00	0.27444273E 00
15	0.27444273E 00	0.29403508E 00
16	0.29403508E 00	0.31362742E 00
17	0.31362742E 00	0.33321977E 00
18	0.33321977E 00	0.35281211E 00
19	0.35281211E 00	0.37240446E 00
20	0.37240446E 00	0.39199680E 00
21	0.39199680E 00	0.41158915E 00
22	0.41158915E 00	0.43118149E 00
23	0.43118149E 00	0.45077384E 00
24	0.45077384E 00	0.47036618E 00
25	0.47036618E 00	0.48995972E 00

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